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Operation UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS

March - June 1953

Statement A
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C. J. Montie for Chief, ISCM/DN

Project 9.6

PRODUCTION STABILIZATION [redacted]

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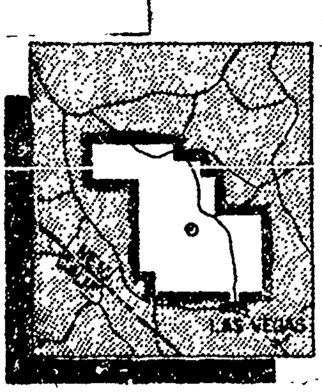

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OPERATION UPSHOT-KNOTHOLE

Project 9.6

PRODUCTION STABILIZATION

REPORT TO THE TEST DIRECTOR

by

Belmon Duval
Charles S. Adler, Capt., USA
Willard J. Turnbull

December 1953

CJ Montie
for Chief, TSCM/DNA

RESTRICTED DATA

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Waterways Experiment Station
U. S. Army Corps of Engineers
Vicksburg, Mississippi

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ABSTRACT

The objective of stabilizing the soil in the Frenchman Flat test area was to minimize the detrimental effects to technical photography of the dust clouds rising due to thermal radiation and high wind velocities directly associated with the shock wave.

Approximately 700,000 sq yd of 2 in. thick sand-cement mat were laid 2000 to 12,000 ft from ground zero. Included in this area was 3000 sq yd of surface area sprayed with sodium silicate. The silicate was used to stabilize the mounded-over portions of buried structures where these structures fell within a cement stabilized area.

The stabilization project was for the most part successful. Motion picture coverage was far better on this operation than on previous ones because the dust and smoke was held to a minimum. The stabilization was particularly effective during the thermal phase and early moments of the blast phase. The use of sodium silicate as a supplement to the basic sand-cement stabilization in patch-work as well as for stabilizing specific areas proved to be fast, feasible, and practicable.

FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation UPSHOT-KNOTHOLE, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, Summary Report of the Technical Director, Military Effects Program. This summary report includes the following information of possible general interest.

a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots.
b. Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation.
c. Compilation and correlation of the various project results on weapons effects.
d. A summary of each project, including objectives and results.
e. A complete listing of all reports covering the Military Effects Tests Program.

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The assistance of the following personnel and organizations is gratefully acknowledged by the authors:

Mr. W. L. Harrison of the District Engineer's Office, Louisville, Ky., who acted as the project engineer for the field construction.

Mr. R. L. Tolbert, Soils and Cryology Branch, Engineer Research and Development Division, Military Operations, Office of the Chief of Engineers, U. S. Army who coordinated all work performed by the laboratories listed below:

Waterways Experiment Station, Vicksburg, Miss.
Engineer Research and Development Laboratories, Ft. Belvoir, Va.
Ohio River Division Laboratories, Cincinnati, Ohio

Also acknowledgment is made for the guidance of Col. G. B. Page and his staff of Hq, AFSWP for the initial planning.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The purpose of the soil stabilization of selected areas in Frenchman Flat at the Nevada Proving Grounds (NPG) was to provide surfaces that would minimize the detrimental effects of the dust clouds arising due to thermal radiation and high wind velocities associated with the shock wave. All or part of these effects cause the generation of smoke and dust particles which rise from the natural ground surface. These smoke and dust particles were in sufficient amounts to obscure structures and equipment whose behavior under nuclear detonation was being observed by means of high speed photography. Many projects relied to a great extent on high speed motion picture coverage of their structures or equipments to evaluate the results of the atomic detonation thereon. Without the stabilization these projects could not have fulfilled their objectives since motion picture coverage would not have been successful.

1.2 BACKGROUND

On 18 September 1952 the Armed Forces Special Weapons Project (AFSWP), requested the Chief of Engineers to study means of stabilizing the ground surface in certain areas of the NPG. Under the direction of the Soils and Cryology Branch, Engineer R & D Division, Office Chief of Engineers, USA, the project was assigned to the Waterways Experiment Station, Vicksburg, Miss., with the Engineer Research and Development Laboratories, Fort Belvoir, and the Ohio River Division Laboratories, Cincinnati, Ohio, directed to assist. The results of the laboratory and field studies completed in January, 1953, indicated that the naturally occurring surface soils in the Frenchman Flat lake bed area could not be satisfactorily stabilized by any inexpensive procedure but that the surface materials from nearby talus slopes could be used by a modified soil-cement stabilization procedure. The studies also indicated that for less critical areas sodium silicate penetration procedure might be satisfactory.

CHAPTER 2

STABILIZATION CRITERIA

2.1 GENERAL

The assignment of the problem of surface stabilization set up criteria of blast and thermal radiation against which the stabilized surface offered satisfactory resistance. These were as follows:

A. Methods of stabilization were desired which would be effective over various effects ranges to the maximum indicated below:

(1) Peak overpressure of 25 psi.

(2) Peak gust velocity 550 mph, average gust velocity of 250 mph, and a gust duration of about ½ sec. (For a 20 KT weapon at 25 psi.) For other yields at the same overpressure the gust velocity is the same and the duration varies approximately as $W^{1/3}$.

(3) Total thermal flux of 50 cal/cm^2 1/.

B. The load bearing capacities of the stabilized areas in each of the effects ranges fell into two categories:

(1) No bearing capacity required - the only requirements are those outlined in paragraph A above. Soil stabilization for those areas was required to withstand the effects of the explosion. It was intended that there would be no traffic over the areas.

(2) Bearing capacity sufficient for the dead weight of various types of equipment, such as aircraft and vehicles. The wheeled equipment was towed into position.

2.2 PHENOMENA INVOLVED

In an atomic detonation in the NPG area smoke, dust, and possibly some steam are generated over the ground surface with the arrival of the thermal pulse. The dust is produced at least in part by a so-called popcorn effect in which the soil particles exposed to intense heat

1/ Paragraph 3 of Minutes of Conference, 24 October 1952, Appendix I to First Interim Report, Stabilization of Soil Areas Affected by Nuclear Detonations, Soils of the Frenchman Flat Area, Nevada Proving Grounds, February 1953.

explode, thereby ejecting many smaller sized particles. The true nature of this phenomenon is not fully understood. In addition to the popcorn effect, smoke also appears to be generated by organic material in the soil. Samples of the smoke and dust indicated that a large percentage of the particles were smaller than 1 micron in size. The smoke and dust are carried vertically in the air by thermal currents generated by the heat. The arrival of the shock wave produces further disturbance and causes the smoke and dust to rise higher above the ground surface. High velocity winds arriving shortly thereafter tend to suddenly increase the horizontal and vertical movement of these particles with an over-all effect of obscuring vision in the area.

2.3 INVESTIGATIONS

Initial Studies 2/ indicated that the smoke and dust effects produced by the heat and carried upward by the thermal currents were the principal difficulties to be solved. Fairly ample evidence was furnished from previous experience that the pressure effects of the blast are not unduly severe except possibly in the immediate area of ground zero. Photographic evidence indicated that the thermal flux occurred almost simultaneously with the detonation and that there was an increasing time lag between the thermal flux and the shock front depending on distance and height of burst. The high velocity winds caused by the atomic detonation suddenly reversed in direction but with considerably less intensity. In considering these time lags it was apparent that adequate soil stabilization both in front and to the rear of an object being studied should eliminate the smoke and dust and thus eliminate obscuration in the sight line of the high speed cameras. The length of the areas to be stabilized varies depending on the location of objects in the test area.

The problem resolved into one in which a stabilized material must be placed on the surface of the ground which will successfully resist the heat effects in that the amount of smoke, dust, and possibly steam generated is insufficient to cause obscuration of the subject. In addition, in the vicinity of the blast area and for some distance from ground zero the particles of the stabilized surface should be tied together securely enough to resist displacement by high wind velocities. Displacement of soil particles, even fine sand sizes, would tend to produce obscuration and also would be a hazard to photographic equipment as well as certain types of structures and equipment under study. In addition, the surface of the stabilized material must be of sufficient smoothness and hardness so that undue abrasion is not occasioned by vehicular movement. The thickness and strength must also be adequate to carry all loads to which it may be subjected.

After careful study of available information, a comprehensive laboratory investigation of possible methods and materials was made by the three cooperating organizations 3/. The results of this investigation

2/ Ibid

3/ Waterways Experiment Station, Vicksburg, Miss. Engineer Research & Development Laboratories, Fort Belvoir, Va., Ohio River Division Laboratories, Cincinnati, Ohio.

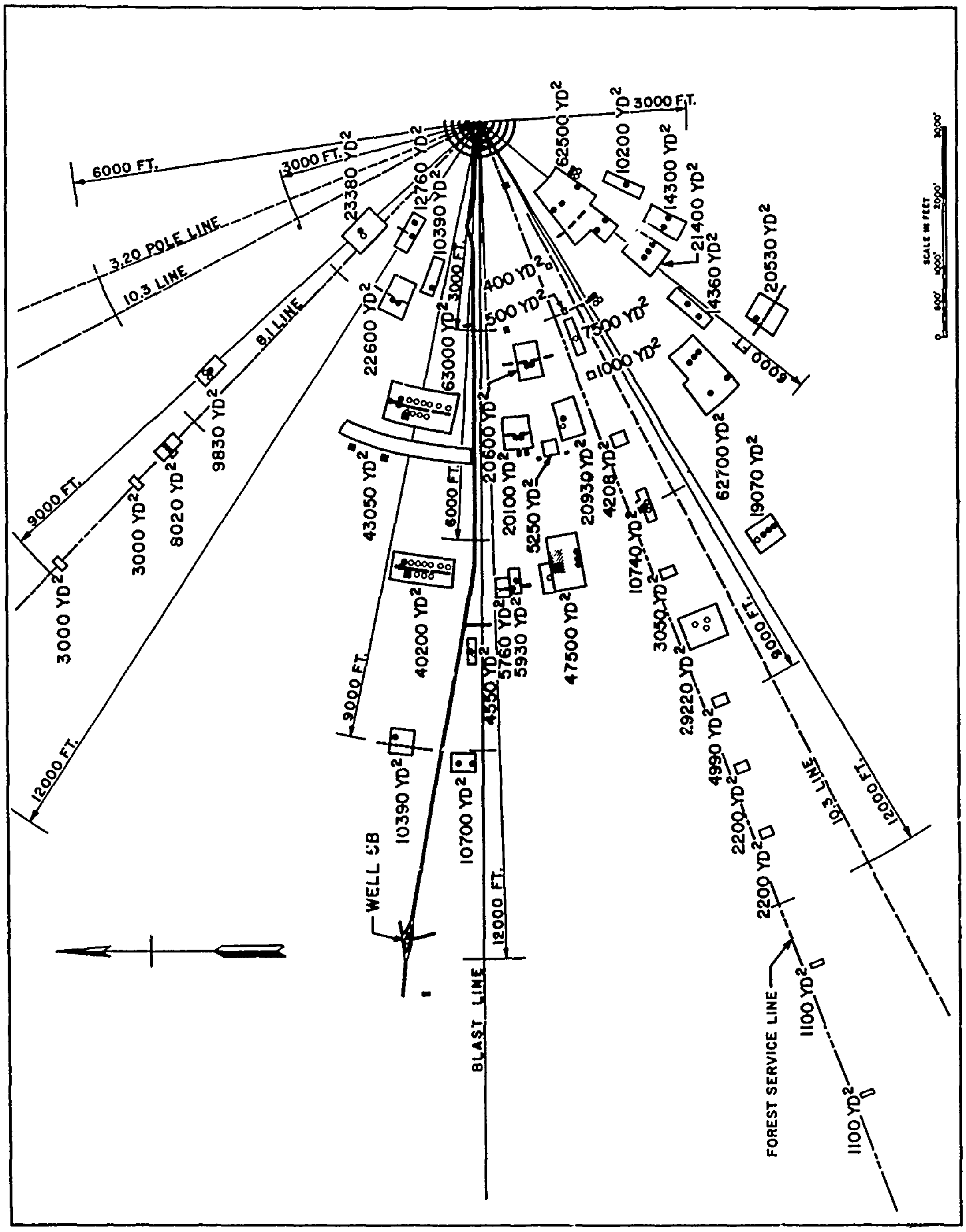

Fig. 2.1 Sand-Cement Stabilized Areas

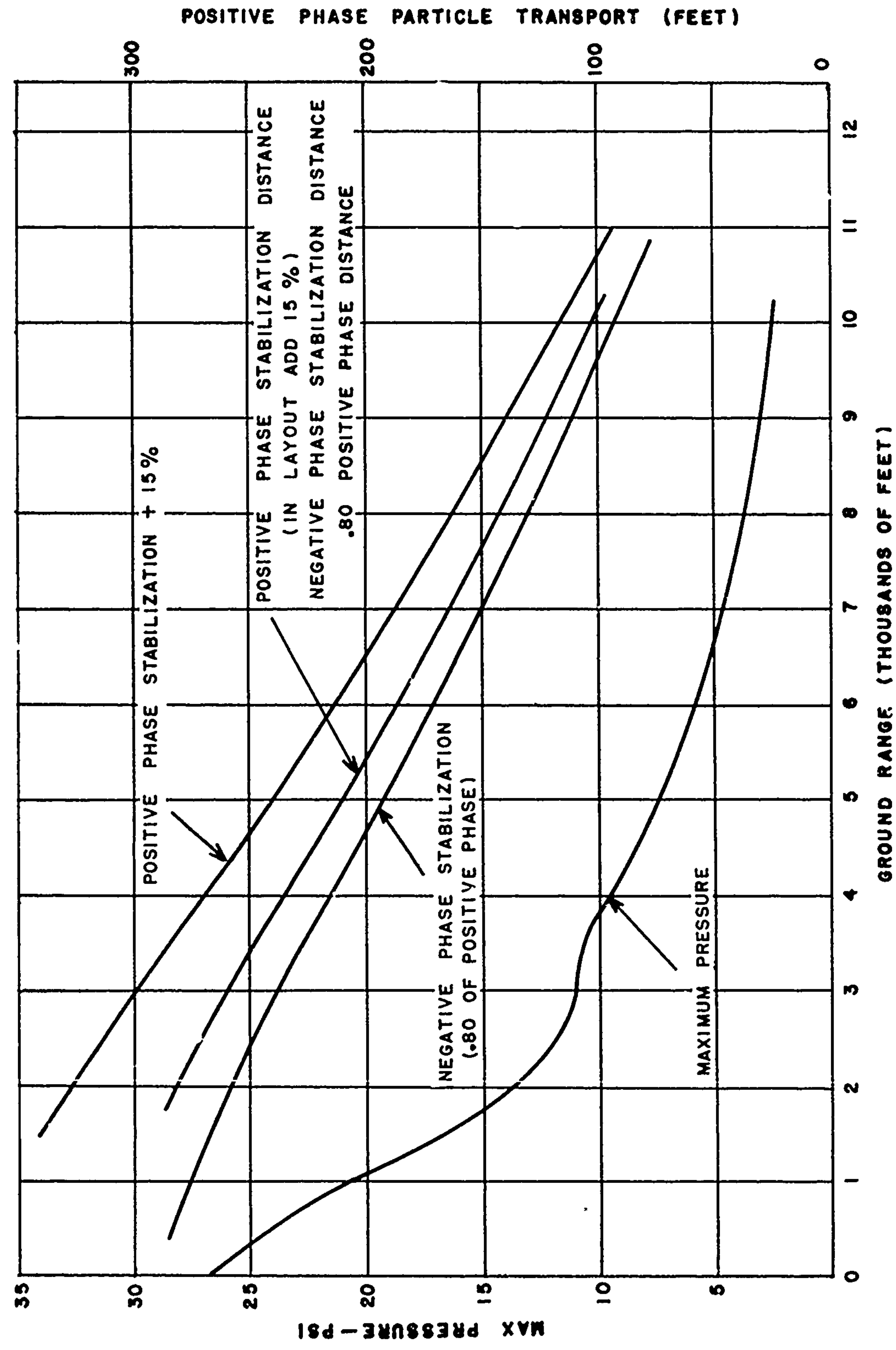

Fig. 2.2 Stabilization Criteria

and the recommendations of the Chief of Engineers to the AFSWP are given in a report 4/ dated February, 1953. Briefly these recommendations were for a 2 in. thick sand-cement stabilized surface with a partial alternate for non-critical areas of a sodium silicate penetration treatment.

2.4 STABILIZED AREAS AND SPECIFICATIONS

The plan for the specific areas stabilized is shown in Fig. 2.1. The Corps of Engineers specifications for the stabilization are given in Appendix A. The criteria for specific area length are shown in Fig. 2.2. An arbitrary figure of 50 ft was used for the lateral boundary on each side of the target.

4/ Op. cit., Page 14

CHAPTER 3

CONSTRUCTION

3.1 CONSTRUCTION DIRECTIVES

The sand-cement stabilization project was accomplished under the following Engineering Memoranda and Work Orders to or issued by the Field Manager, Las Vegas Field Office, Atomic Energy Commission (AEC), Mercury, Nevada, to the Reynolds Electrical and Engineering Company, Mercury, Nevada:

DWET, E/C, Eng. Memo No. 179, 30 January 1953
DWET, E/C, Eng. Memo No. 262, 18 February 1953
DWET, E/C, Eng. Memo No. 300, 28 February 1953
DWET, E/C, Eng. Memo No. 309, 5 March 1953
Work Order No. CON 53-85, 25 February 1953
Work Order No. CON 53-85-A, 16 March 1953
Work Order No. CON 53-85-B, 16 March 1953
Work Order No. CON 53-85-C, 17 March 1953
Work Order No. CON 53-85-D, 17 March 1953
Work Order No. CON 53-85-E, 17 March 1953
Work Order No. CON 53-85-F, 30 April 1953

3.2 CONSTRUCTION

A list of the equipment required for the construction of the sand-cement stabilized cement is given in Table 3.1. This table includes standby equipment maintained in order to avoid delays in case of breakdowns. Also included in this table as a matter of secondary information, are the rental rates for this equipment paid by the contractor. A "line-up" of this equipment in the order used in stabilizing each area is shown in Figs. 3.2, 3.3, 3.4 and 3.5. Table 3.2 gives in detail the rate of progress in stabilizing the required areas as shown in Fig. 2.1. The criteria establishing the length of each individual stabilized area is shown in Fig. 2.2.

3.2.1 Materials Used

The sand used for the stabilization was obtained from a borrow pit in the Frenchman Flat area and is further described under section 3.3.2. Approximately 63,000 tons of the processed sand were used.

The Portland cement was furnished by four different producers in the Southern California Area. These were the Monolith Portland Cement Company, Monolith; the California Portland Cement Company, Colton; the Southwestern Portland Cement Company, Victorville; and the Riverside Cement Company, Riverside. A total of 21,463 barrels of Portland cement was required.

Approximately 154,000 lb of calcium chloride were used as an integral curing agent. This was furnished through the General Services Administration by Broem, Knecht, and Heinan of San Francisco, and shipped from a Los Angeles warehouse.

The water required for preparation of the subgrade sand-cement mixture and for limited water curing of completed sand-cement stabilized areas was obtained from the wells operated by the AEC approximately 2.5 miles from ground zero. A total of approximately 5,250,000 gal of water was used for all operations.

The concentrated (38% solids) sodium silicate was furnished by the Philadelphia Quartz Company, Los Angeles. Approximately 27,000 gal were used for stabilization and "touch-up" prior to Shot 9 and approximately 23,000 gal were used prior to Shot 10. Four parts of the concentrated sodium silicate were diluted with one part of water prior to application.

3.3 GENERAL CONSTRUCTION PROCEDURE

3.3.1 Subgrade Preparation

Construction areas, trenches, and foundation excavations necessitated by equipment placement and test structures were backfilled and consolidated. The general areas to be stabilized were brought to the proper grade (Fig. 2.1) and surface uniformity with motor graders.

3.3.2 Borrow Pit Operation

The borrow area was located along the main entry road to Frenchman Flat, approximately 3 miles from ground zero. Excavation for borrow material was limited to a depth of about 4 ft. The borrow material was uniform in grading with the exception of a small percentage over 3/4 in. and a few cobbles. It was prepared for use by removal of the cobbles and passing the balance through a Pioneer Portable Crusher (Fig. 3.6) which reduced the borrow material to 3/4 in. maximum size. This crusher-run material was then stockpiled for use without further processing. The grading of this material remained very uniform without controls and an average gradation was:

Sieve Size	Per cent Passing
3/4 in.	100.0
1/2 in.	97.2
3/8 in.	94.0
No. 4	83.6
No. 8	72.5
No. 16	59.8
No. 30	45.5
No. 50	30.6
No. 100	16.9
No. 200	8.4

3.3.3 Wetting Subgrade

At the start of stabilization operations subgrade moisture content and relative humidity of the atmosphere were appreciably below that anticipated during planning of the stabilization procedure. Consequently, prior to the placement of the processed borrow pit material the subgrade was sprinkled using a gravity sprinkler truck. The rate of application varied appreciably according to conditions in each area. It is estimated that the average rate of water applied was approximately 1.5 gal of water per square yard. This was necessary to properly condition the subgrade for compaction and to eliminate the action of the subgrade drawing water from the mixed sand-cement overlay and thereby causing extensive cracking.

3.3.4 Placement of Materials

The crusher-run borrow materials were hauled to the stabilization areas by 11-ton capacity trucks and dumped into an equalizer spreader box. This spreader box uniformily placed the borrow material in the predetermined sized windrow. Cement and water were then uniformly added to the windrow so that prior to mixing, properly proportioned windrow contained, per linear foot, the following:

362 lb of borrow material at 4 per cent original moisture
20.9 lb of Portland cement
14.5 lb of water

The above quantities were sufficient for a lane 18 ft wide, 1 ft long, and 2 in. thick of consolidated stabilization.

3.3.5 Mixing Materials

The prepared windrow was picked up in a "Wood Model 42 Roadmixer" (Fig. 3.5) manufactured by the Wood Manufacturing Company, North Hollywood, Calif. Additional water at an average rate of 29.2 lb per linear foot of windrow was added during the mixing operation. This additional water contained dissolved calcium chloride in an amount such that approximately 1/2 lb of calcium chloride was added for each 20.9 lb of Portland cement. The mixed material was discharged from the Wood's Mixer in a windrow.

3.3.6 Spreading and Compaction

The mixed windrow was spread to the required uncompacted thickness by motor graders. This operation was followed by initial compaction by means of one pass of a conventional straight 13 wheel pneumatic-tired roller loaded to 11,000 lb with tires inflated to 30.5 psi. The motor grader blading and one pass of the pneumatic-tired roller were repeated to obtain a reasonably smooth surface. Again the surface was bladed to a uniform surface condition and followed by 18 to 24 passes of the pneumatic-tired roller to obtain the desired compaction. The surface texture of a typical stabilized area is shown in Fig. 3.7.

3.3.7 Curing

Based on laboratory tests and meager weather reports from the Las Vegas, Nevada, U. S. Weather Bureau Station, it was believed that with the relative humidity obtained during the proposed construction period, the use of calcium chloride as an integral curing agent would be satisfactory. However, it was found at an early date during the construction that if the compacted surface was not further treated excessive shrinkage with attendant cracking occurred. This was partially due to a lower relative humidity than expected (7% to 15%). The condition of detrimental cracking was practically eliminated by water sprinkling of limited extent for the remainder of the stabilized areas. Thorough water curing was impossible because of the limited quantity of water available for this purpose.

3.3.8 Clean-up Operations

The primary clean-up of the stabilized areas was made by Wilshire Sweepers purchased by the government. The sweepers were self-propelled with an effective width of 48 in. and an average daily coverage rate of 20,000 sq yd. The entire stabilized surfacing with the exception of those areas in the 3.6 project were thoroughly broomed from 20 April to 4 May 1953.

The final clean-up was started on 5 May and operations were continuous through 6 May on certain high priority areas. The three sweepers, previously mentioned, were supplemented by two operating sweepers and one standby machine which were furnished by the manufacturer for the final clean-up. It is of interest to note that the carry-back of dust onto the cleanly swept areas was negligible during a severe dust storm on 6 May.

3.3.9 Rate of Progress

Initial base preparation work was started on 17 March and the actual construction of the sand-cement stabilized overlay on 19 March. The stabilization work was completed on 22 April. The square yardage of completed stabilization accomplished each day is shown in Table 3.2 Primary brooming was started on 20 April and completed 4 May. The rate of progress for the brooming operation is shown in Table 3.3. Final brooming of critical areas was performed on 5 and 6 may. The sodium silicate was first applied on 28 April and completed on 6 May.

The rate of progress was excellent and each phase of the work was completed in advance of the scheduled date.

3.4 THE USE AND EFFECTIVENESS OF SODIUM SILICATE

Sodium silicate was used as a stabilizing agent on the 3.16b structure and as an expeditious means of repairing the damaged areas of the sand-cement stabilization. The 38 per cent sodium silicate concentrate was diluted with one part of water to four parts of sodium silicate. Application was by means of a pressure pump mounted on a tank truck which discharged either through a nozzle or a spray bar, depending on the size of the area requiring treatment. The rate of application was from 2 gal to 2-1/2 gal/sq yd and was governed by the condition of the surface. The depth of the penetration varied from 3/8 to 5/8 in.

The sodium silicate stabilization of the 3.16b project covered 2200 sq yd. The soil at this location was quite fine with over 20 per cent of the material passing the 200 mesh sieve. Consequently, less penetration was obtained with the liquid in this area but the effectiveness of the treatment was considered adequate since it was some 12,500 ft from ground zero.

The sodium silicate was a most effective and rapid means of repairing loosened areas of the sand-cement stabilization. The rate of application was approximately one half that used for full stabilization and the maximum penetration was obtained on the sand aggregate. Sodium silicate is an excellent stabilizing agent, but the purchase price of the material for an extensive program is prohibitive. Areas entirely stabilized with the sodium silicate will not withstand vehicular traffic thus precluding the use of large quantities of this type of stabilization.

3.5 CONSTRUCTION DIFFICULTIES

It has been previously noted in this report that the extremely low relative humidity of 7 to 15 per cent presented numerous difficulties in the processing and curing of the sand-cement stabilization. This necessitated the development of more rapid processes for the placing of the sand-cement surfacing and the adding of moisture to the surface during initial curing periods to alleviate surface cracking. Neither of these requirements had been included in the construction planning since an abnormally dry season was not anticipated.

A secondary difficulty was brought about by the fact that the various using agencies did not fully appreciate the importance of the stabilization program to their respective projects until the stabilization was practically completed. This resulted in numerous and repeated clean-up operations and repairs which could have been avoided through proper planning. This apparent disregard for the need for protecting the stabilization areas resulted in the extensive use of sodium silicate as a patching medium on previously stabilized areas which had become defective either under an abnormal and an unnecessary amount of vehicular traffic by the using agency or as a result of the latter digging holes in the stabilized areas for equipment placement.

TABLE 3.1 - Equipment Used by Reynolds Electrical and Engineering Co., Mercury, Nevada

Number	Type	Owner	Time Used	Rental Rate
G 5562	Cement Screw	Clyde Woods and Son	297 Hours	$ 4.00 per hr
G 5563	1500 Gal. Water Trailer	Clyde Woods and Son	135 "	2.00 " "
G 5564	Mod. 42 Woods Mixer	Clyde Woods and Son	297 "	24.00 " "
G 5565	Mod. 42 Woods Mixer	Clyde Woods and Son	297 "	24.00 " "
G 5575	3000 Gal. Water Trailer	Clyde Woods and Son	297 "	2.00 " "
R 489	Cement Distributor	Clyde Woods and Son	297 "	14.00 " "
G 4522	Pneumatic Roller	Wells Cargo	45 Days 1/	136.00 " mo.
G 4535	Cat. Motor Grader	Carter and Schnieder	45 "	960.00 " "
G 4537	Cat. Motor Grader	Vern Bloxham	45 "	960.00 " "
G 4538	Cat. Motor Grader	Vinnell	45 "	960.00 " "
G 4540	Tandam Roller	Vinnell	45 "	365.00 " "
G 4541	Minn. Moline Wheel Tractor	Vinnell	45 "	210.00 " "
G 4542	Int'n Wheel Tractor	Vinnell	45 "	210.00 " "
G 4543	Pneumatic Roller	Vinnell	45 "	210.00 " "
G 4544	Pneumatic Roller	Vinnell	45 "	210.00 " "
G 4545	Pneumatic Roller	Vinnell	45 "	185.00 " "
G 4546	Case Wheel Tractor	Vinnell	45 "	210.00 " "
G 4547	Int'n Wheel Tractor	Vinnell	45 "	210.00 " "
G 4548	Pneumatic Roller	Vinnell	45 "	185.00 " "
G 4549	Cat. Motor Grader	Vinnell	45 "	960.00 " "
G 4550	Cat. Motor Grader	Vinnell	45 "	960.00 " "
G 4556	Cat. Skip Loader	Carter and Schnieder	45 "	855.00 " "
G 4557	Caterpillar Tractor	Industrial Construction Co.	45 "	1,129.00 " "
G 4558	Caterpillar Scraper	Industrial Construction Co.	45 "	680.00 " "
G 4559	Sheepsfoot Tamper	Vinnel	45 "	110.00 " "
G 4563	Cat. Motor Grader	Wells Cargo	45 "	960.00 " "
G 4564	Case Wheel Tractor	Vinnel	45 "	325.00 " "
G 4565	Case Wheel Tractor	Vinnel	45 "	350.00 " "
G 4566	Pneumatic Roller	Vinnel	45 "	200.00 " "

TABLE 3.1 (cont'd)

Number	Type	Owner	Times Used	Rental Rate
G 4567	Pneumatic Roller	Vinnell	45 days	$ 200.00 per mo.
G 4568	Case Wheel Tractor	Vinnell	45 "	350.00 " "
G 4569	Bucyrus Erie Shovel	Espy Brothers	5 "	9.75 " hr
G 5035	Lodi Steam Cleaner	Atomic Energy Commission	44 hr	.75 " "
G 5588	Madsen Batch Plant	Las Vegas Building Materials	45 days	2,000.00 " mo.
G 7514	4000 Gal Tank Trailer	Asbury Transportation Co.	45 "	250.00 " "
R 516	Water Truck	Cox Motor Co.	45 "	1,000.00 " "
R 485	Water Truck	Carter and Schnieder		425.00 " "
R 466	Sterling Tractor & Trailer	Mercury Transport Co.		1,000.00 " "
R 486	GMC Water Truck	Carter and Schnieder		475.00 " "
R 487	Diamond T Water Truck	Vinnell		550.00 " "
R 488	GMC Water Truck	Vinnell		550.00 " "
R 492	GMC Tractor & Tank Trailer	Mercury Transport Co.		1,000.00 " "
G 7505	Quick Way Crane	Reynolds Electrical and Engineering Co.		

Note: Number of days is approximate

TABLE 3.2 - Rate of Progress, Stabilization

Date (1953)	Sq Yd This Date	Sq Yd To Date	Density lb/cu ft	Moisture % Dry Wt.
March 16				
17			123.0	10.0
18			123.0	5.6
19	16,000	16,000		
20	15,400	31,400	113.0	9.1
21	23,100	54,500	116.0	9.6
23	26,400	80,900	117.3	-
24	17,680	98,580	130.3	-
25	17,560	116,140	118.0	9.3
26	21,910	138,050		
27	22,000	160,050	118.0	9.5
			130.2	8.6
28	14,480	174,530	113.8	10.2
30	21,600	196,130		
31	21,640	217,770		
April 1	17,900	235,670	115.0	8.2
2	31,090	266,760	118.5	7.4
3	21,650	288,410	118.5	10.0
4	22,350	310,760		
6	22,690	333,450	114.0	7.5
7	21,070	354,520		
8	32,380	387,900	120.0	8.5
9	35,440	423,340		
10	28,250	451,590		
11	21,450	473,040	118.0	-
13	38,590	511,630		
14	32,620	544,250		
15	25,120	569,370		
16	33,570	602,940		
17	17,000	619,940		
18	23,800	646,840	123.0	12.1
20	23,320	670,160		
21	13,000	683,160		
22	10,000	693,160	Stabilization Completed	

TABLE 3.3 - Rate of Progress, Primary Brooming

Date (1953)	Sq Yd of Primary Brooming	
	This Date	To Date
April 20	12,000	12,000 (started)
21	30,000	42,000
22	32,050	74,050
23	32,990	107,040
24	62,500	169,540
25	60,000	229,540
27	45,900	275,440
28	54,360	329,800
29	62,230	392,030
30	56,530	448,560
May 1	66,640	515,200
2	36,930	552,130
4	60,260	612,390

Note: The apparent discrepancy between the primary brooming yardage and the total area stabilized is due to the fact that all or portions of the four areas in the 3.6 project were not used on this test.

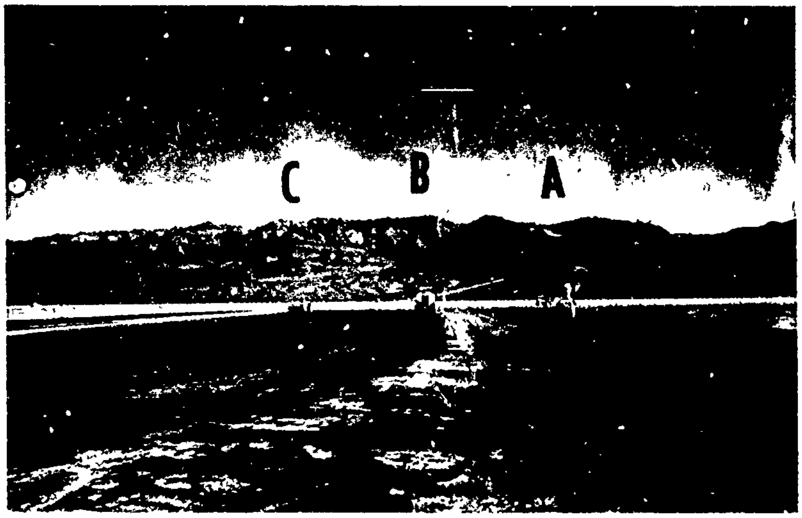

Fig. 3.1 Subgrade Preparation. A. Initial grading and leveling by motor blade. B. Addition of water by gravity discharge truck. C. Compaction of subgrade by pneumatic roller.

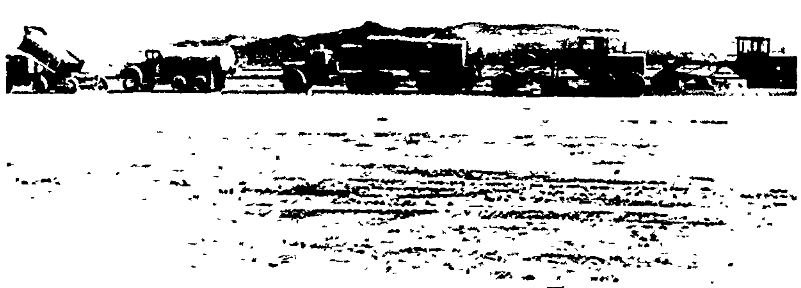

Fig. 3.2 String-out of Aggregate Spreading Equipment. From left to right: dump truck discharge into aggregate equalizing spreader, tank truck adding moisture to the dry aggregate, bulk cement truck spreading cement through calibrated gates, motor graders windrowing moistened aggregate.

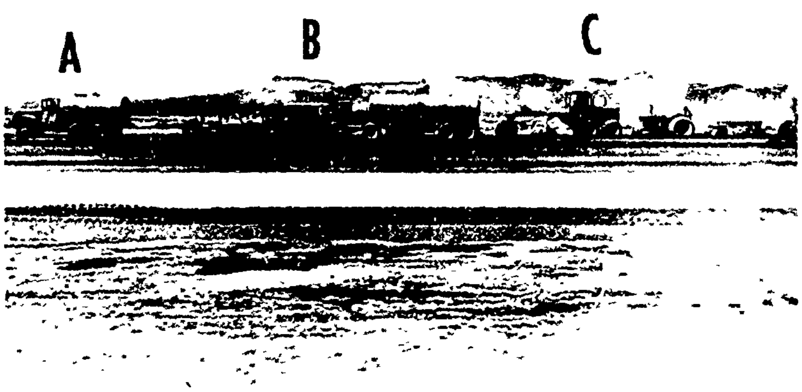

Fig. 3.3 Continuity of Mixing Operations. A. Water truck adding moisture through 2 in. discharge immediately ahead of mixer. B. Wood's mixer with attached tank truck containing mixing water. C. Motor grader and pneumatic roller making initial spread of windrow and compaction.

Fig. 3.4 Final Phase of Spreading and Compaction Operations. (This Photo overlaps Fig. 3.3 by one pneumatic roller.) Two motor blades with accompanying pneumatic rollers performing final shaping and compaction operations.

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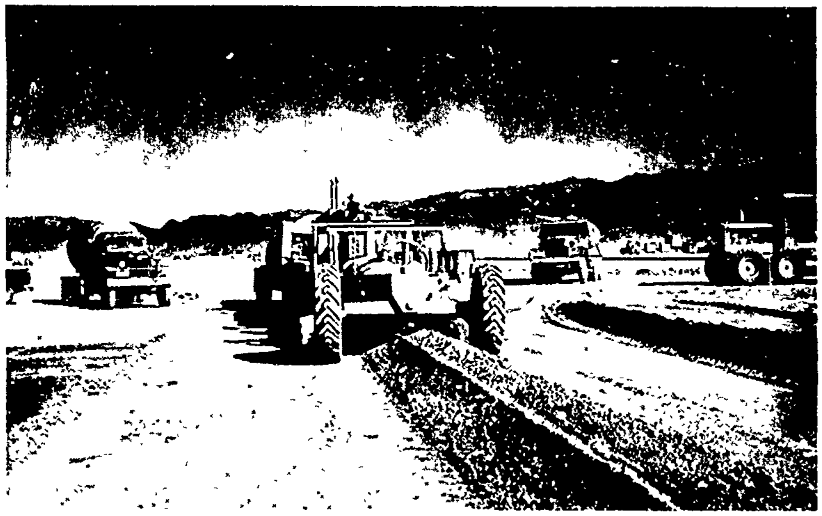

Fig. 3.5 Wood's Mixer Operating on a Previously Moistened Windrow of Cement and Sand Aggregate. Two tank trucks equipped with pressure spray bars used to moisten the subgrade in advance of the lay-down. They were also used to dampen the completed stabilization during the initial curing period.

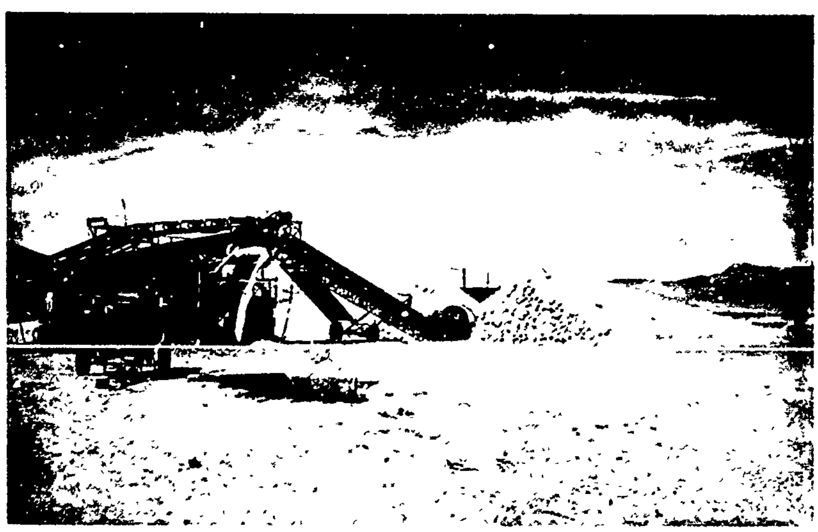

Fig. 3.6 Sand Aggregate Being Processed by a Pioneer Crusher Operated by the Wells Cargo Co., Adjacent to the Project.

Fig. 3.7 Texture of Completed Sand-Cement Stabilization

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CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

It has been demonstrated that the sand-cement stabilization, using two bags of cement per cubic yard, can be satisfactorily constructed under adverse climatic conditions at what might be termed a relatively low cost when compared with many other construction costs at the NPG. In addition, this type of stabilization is adaptable to rapid construction techniques which was a vital consideration on this project. It was further demonstrated that a 2 in. thickness is about the minimum that can be practicably constructed.

The use of sodium silicate as a supplement to the basic sand-cement stabilization in patch work as well as for stabilizing specific strips and areas proved to be a fast, feasible, and practicable field operation.

The stabilization was extremely effective in aiding motion picture coverage of targets through the thermal phase. Very little popcorning was in evidence in any of the motion picture film, even at the stations closest to ground zero.

With the arrival of the positive phase of the blast wave at a camera station, dust was carried onto the stabilized area and at the closer-in stations obscured the targets to some extent. All targets were obscured when the negative phase of the blast wave arrived. However, it is felt that the stabilization was highly effective and that, without it, practically no useful technical motion picture photography would have resulted.

At those stations within the range of 2000 to 3000 ft of ground zero, some physical damage to the stabilization was noted. Figure 4.1 shows the breakup of the surface of a stabilized area that extended from 2000 to 2500 ft from ground zero. Ground zero, in this illustration, is toward the upper central portion of the picture. Post shot examination of the broken areas indicated that the surface failed where the thickness was less than 2 in. or at a poorly constructed joint.

Figure 4.2 shows the damage that was noted on some stabilized areas within 3500 ft of ground zero where the construction joints were

Fig. 4.1 Break-up of Close-in Stabilized Area

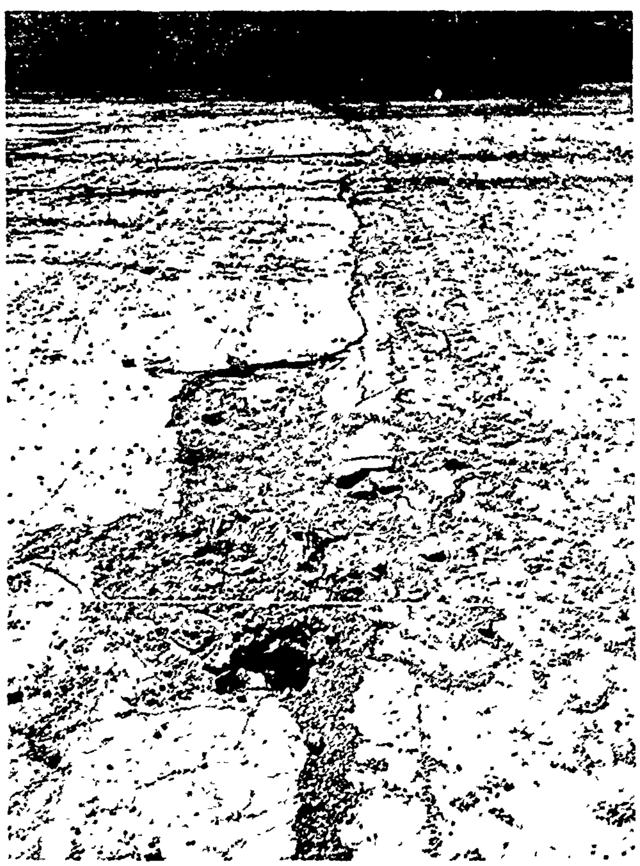

Fig. 4.2 Peeling from Construction Joint

perpendicular to a radial extending from ground zero. This "peeling" of the surface did not interfere with the motion picture coverage.

4.2 RECOMMENDATIONS

1. In future large-scale stabilization projects of this type, every effort should be made to complete the construction work of the project prior to stabilizing the area and to reduce all traffic to the greatest extent possible. More moist curing of the completed sand-cement surface than was possible on this project should be utilized on future projects as one feature which would materially improve the quality of the stabilized product.
2. All construction joints in stabilized areas should be made on radial lines passing through ground zero.
3. On future tests where stabilization is to be employed the areas should be combined to give one continuous, long, radial strip.
4. The use of berms around stabilized areas as a deterrent to vehicular traffic should be employed.

APPENDIX A

SPECIFICATIONS FOR SAND-CEMENT STABILIZED PAVEMENT CAMP MERCURY, NEVADA

A.1 GENERAL

A.1.1 Description

The work covered by these specifications shall consist of sand-cement stabilized pavement having a nominal 2 in. thickness (compacted), and prosecuted in accordance with the requirements of the specifications, and shall conform to the lines, grades, thicknesses and typical cross section shown on the plans.

A.2 MATERIALS

A.2.1 Portland Cement

Portland cement shall comply with all the requirements and tests of Federal Specifications for "Cements, Portland," Design, SS-C-192a, Type I or IA. One cubic foot of Portland cement shall be considered as weighing 94 lb.

A.2.2 Water

The water shall be free from substances deleterious to the hardening of the sand-cement course and shall be subject to the approval of the project engineer.

A.2.3 Sand

The sand to be used shall be selected borrow material from the area shown on the plans, or other sources designated by the project engineer.

A.2.3.1 Borrow Area Preparation

Prior to removal of borrow material for the sand-cement stabilization, all vegetation shall be removed. Approximately 6 in. of surface material in the borrow shall be removed to eliminate inclusion of oversize stones and cobbles in the borrow material.

A.2.3.2 Borrow Excavation Depth

Borrow material from the areas designated shall not be removed to a depth greater than 4 ft.

A.2.3.3 Borrow Area Clean-Up

All pits are to be excavated and backsloped uniformly, and are to be left in a neat, leveled condition with adequate drainage provided.

A.2.4 Calcium Chloride

Calcium chloride shall comply with the requirements of Federal Specification O-C-106a and shall be delivered to the project in 50 or 100 lb multi-wall bags.

A.3 EQUIPMENT

A.3.1 Equipment Description

Any machine, combination of machines, or equipment, may be used to produce the completed sand-cement stabilized area meeting the requirements for borrow material placement, cement distribution, water application, incorporation of other materials, compactions, finishing and providing protection as controlled by these specifications, paragraphs A.4.2 to A.4.9, inclusive.

The machines and equipment used shall be in suitable operating condition in all respects and shall meet with the approval of the project engineer.

A.4 CONSTRUCTION METHODS

A.4.1 Preparation

Before undertaking other construction operations, the area to be paved by the sand-cement mixture shall be graded and shaped as required to construct the paved area conforming to the grades, lines, thicknesses, and typical cross-section shown on the plans. Any additional soil needed shall be placed as directed by the project engineer.

The subgrade shall be firm and able to support without displacement, the construction equipment and compaction required. Any soft or yielding subgrade shall be corrected and made stable before construction proceeds.

A.4.1.1 Placing Selected Borrow Material

Selected borrow material shall be either placed and spread to uniform thickness or placed in a windrow on the subgrade in such quantities as to assure the compacted thickness shown on the plans. If the selected borrow material should become compacted or lumpy, or when directed by the project engineer, it shall be scarified and pulverized before Portland cement is added.

A.4.1.2 Application of Cement

The Portland cement shall be applied uniformly on the borrow material at the rate of 5.2 per cent of weight of borrow material and in a manner satisfactory to the project engineer.

Suitable equipment for handling, weighing and spreading the cement shall be provided.

At the time of cement application, the percentage of moisture in the borrow material shall not exceed the quantity which will permit a uniform and intimate mixture of borrow material and cement during mixing operations.

All the operations specified in paragraphs A.4.1.1 to A.4.1.2 shall be continuous and surface finish completed in daylight hours. All the operations specified in paragraphs A.4.1.3 to A.4.1.4 shall be completed within 6 hr.

Any equipment or traffic traveling over the spread cement shall be maintained at slow speed and any cement displaced shall be replaced before mixing is started.

No cement shall be applied when the borrow material or subgrade is frozen. The air temperature shall be at least 40°F. in the shade and rising.

A.4.1.3 Mixing

After the cement has been applied it shall be mixed with the borrow material. Mixing shall continue until the cement has been sufficiently blended with the borrow material to prevent the formation of cement balls when water is applied.

Any mixture of borrow material and cement that has not been compacted and finished shall not remain undisturbed for more than 30 min.

A.4.1.4 Application of Calcium Chloride and Water, and Moist Mixing

The calcium chloride shall be dissolved in the water to be added to the cement-borrow material mixture. The concentration of the calcium chloride water solution shall be such that when the required moisture content is obtained the calcium chloride added shall be 2 per cent by weight of cement.

NOTE: Normally 100 lb calcium chloride ($CaCl_2 \cdot 2H_2O$ Tech. grade) will dissolve in 18.5 gal of water at 55°F. to yield 21.9 gal of saturated solution. (1 gal of saturated solution equals 4.6 lb calcium chloride.)

Immediately after the borrow material and cement have been mixed, water (containing the calcium chloride solution) shall be applied uniformly and incorporated in the mixture. A water supply and pressure-distributing equipment shall be provided which will assure the application within 3 hr of all water required on the section. After all water has been applied, mixing shall continue until a thorough, uniform and intimate mixture of borrow material, cement and water has been obtained.

When water application and mixing have been completed, the percentage of moisture in the mixture and in unpulverized soil lumps, based on oven-dry weights, shall not be below, nor more than one-fifth above the specified optimum moisture content, and shall be less than that quantity which will cause the base course to become unstable during the compaction and finishing.

The specified optimum moisture content shall be determined in the field by moisture-density test, ASTM Designation: D558-44 or AASHO Standard: T134-45, on representative samples of soil-cement mixture obtained from the base course being processed at the conclusion of moist mixing operations.

A.4.1.5 Compaction

Prior to the beginning of compaction, the mixture shall be in a loose condition for its full depth. As a continuation of mixing operations, the loose mixture shall then be compacted by rolling, until the entire borrow material cement mixture has been uniformly compacted to the density specified by the engineer. The pneumatic-tired rollers shall be of the type, size and weight specified by the engineer as best suited to give the required densities in the mixtures being compacted. The number and the rate of operation of rollers shall be sufficient to uniformly compact the section being processed to the required density within 2 hr.

The specified density shall be determined in the field by a moisture-density test, ASTM Designation: D558-44 or AASHO Standard: T134-45, on representative samples of soil-cement mixture obtained from the pavement being processed at the time of compaction.

A.4.1.6 Finishing

After the mixture has been compacted, the surface of the pavement shall be shaped, if necessary, to the required lines, grades and cross-section. When required, the surface shall be lightly scarified to loosen any imprints left by the compacting or shaping equipment. The resulting surface then shall be thoroughly rolled with steelwheel or pneumatic-tire rollers or both, of the type and size specified by the engineer. Rolling shall be supplemented by broom dragging if required by the engineer. The moisture content of the surface material must be maintained at not less than its specified optimum moisture content during all finishing operations. Surface compaction and finishing of the section being processed shall be done in such a manner as to produce, in not longer than 2 hr, a smooth, dense surface, free of surface compaction planes, cracks, ridges or loose material. The completed pavement shall conform to the grades, lines and typical cross-section shown on the plans. When directed by the project engineer, surface finishing methods may be varied, provided a smooth, dense surface, free of surface compaction planes, is produced.

Any portion of the pavement which has a density of 5 lb or more below that specified by the engineer shall be corrected or removed and replaced to meet these specifications.

A.4.1.7 <u>Protection</u>

Any finished portion of the pavement adjacent to construction which is traveled by equipment used in constructing an adjoining section shall be protected in such a manner as to prevent equipment from marring or damaging the completed work.

At any time when the air temperature may be expected to reach the freezing point during the day or night, sufficient protection shall be given the soil-cement to prevent its freezing for 7 days after placement and until the soil-cement has hardened.

A.4.1.8 <u>Construction Joints</u>

At the end of each day's construction a straight transverse construction joint shall be formed by cutting back into the completed work to form a true vertical face, and by installing a temporary wooden header if required by the project engineer.

The pavement shall be built in a series of parallel lanes of convenient length and width meeting the approval of the project engineer. Straight longitudinal joints shall be formed at the edge of each day's construction by cutting back into the completed work to form a true vertical face free of loose or shattered material.

A.4.1.9 <u>Traffic</u>

Normally, local traffic and construction equipment shall not be permitted to use completed pavements for at least 72 hr after placement and provided such traffic does not crack, mar, or distort the pavement. The opening of any completed area to traffic shall be subject to the approval of the project engineer.

A.4.1.10 <u>Maintenance</u>

The contractor shall be required within the limits of his contract, to maintain the entire base course in good condition and satisfactory to the engineer from the time he first starts work until all work shall have been completed and accepted. Maintenance shall include immediate repairs of any defects that may occur either before or after the cement is applied, which work shall be done by the contractor at his own expense, and repeated as often as may be necessary to keep the area continuously intact. Repairs are to be made in a manner to insure restoration of a uniform surface and durability of the part repaired. Faulty work shall be replaced for the full depth of treatment. Any low areas shall be remedied by replacing the material for the full depth of treatment rather than adding a thin layer of soil-cement to the completed work.

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